AUG 4 1921

VOL. 48 JUNE, 1921 No. 6

BULLETIN

OF THE

TORREY BOTANICAL CLUB

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PUBLISHED FOR THE CLUB

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

THE BAHAMA FLORA

BY NATHANIEL LORD BRITTON
Director-in-Chief of the New York Botanical Garden

AND CHARLES FREDERICK MILLSPAUGH
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An octavo volume of 695 pages. Price $6.25, which includes postage

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LORILLARD MANSION BRONX PARK, NEW YORK CITY

THE BRYOLOGIST

PUBLISHED BY THE

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Please mention the "Bulletin" when answering advertisements.

Vol. 48 No. 6

BULLETIN

OF THE

TORREY BOTANICAL CLUB

JUNE, 1921

Notes on Rosaceae—XIII

PER AXEL RYDBERG

ROSES OF THE COLUMBIA REGION

In this region I here include the states of Oregon and Washington, together with British Columbia and northern Idaho. Most important are the roses of the Cascade Mountains. In the northern part many of the species of the Rocky Mountains have invaded the region, not only on the western slopes of the Rockies but also in the Cascades; in the Siskiyou Mountains of southwestern Oregon there are also found some Californian species; and in eastern Oregon some of those belonging to the Great Basin are found. Since my revision in the North American Flora we have received in exchange a collection from British Columbia, from the Geological Survey of Canada; and Professor J. K. Henry of the University at Vancouver has sent in another collection for determination. Also, I have seen collections from southeastern Oregon made by Miss Eastwood and Dr. Rehder for the Arnold Arboretum.

Key to the groups of species

Styles much exserted, about equaling the stamens; stipules adnate; sepals reflexed, deciduous: styles united; stem climbing, with curved prickles. I. SYNSTYLAE.

Styles not exserted, or only slightly so: stigmas forming a head closing the mouth of the hypanthium.

Pistils numerous; styles as well as the upper part of the hypanthium persistent.

[The Bulletin for May (48: 141–158. *pl. 3*) was issued May 25, 1921.]

Stem climbing, with scattered prickles, rarely with intermixed bristles; sepals more or less lobed; foliage glandular-punctate, sweet-scented.	II. CANINAE.
Stem not climbing, at least the young shoots bristly; prickles infra-stipular or lacking; sepals entire or the outer sometimes with one or two lobes; foliage not very sweet-scented.	III. CINNAMOMEAE.
Pistils few; styles deciduous with the upper part of the hypanthium, which falls off like a ring.	IV. GYMNOCARPAE.

I. SYNSTYLAE

Stipules pectinately lobed and glandular-ciliate; corymb many-flowered.	1. *R. multiflora.*
Stipules merely serrate; corymb one- to few-flowered.	2. *R. arvensis.*

1. ROSA MULTIFLORA Thunb.

See my notes in the preceding paper of this series.* The species has been reported as a ballast plant at one station in Washington.

2. ROSA ARVENSIS Huds.

The following specimens were sent to me by J. C. Nelson, principal of the high school at Salem, Oregon, for determination. In the accompanying letter Mr. Nelson wrote among other things: "He [the collector] reports this form as common in the vicinity of Vancouver [Washington], apparently fully spontaneous. The flowers were always single, and the petals of a wonderful shade of pearly white." The specimens apparently belong to the so-called Ayrshire Rose, which is by some regarded as a form of *R. arvensis*, by others as a hybrid of the same. The leaflets are larger and more pointed and the sepals more inclined to be lobed than in the wild English form of that species.

WASHINGTON: Vancouver, *R. V. Bradshaw 1053*.

II. CANINAE

Leaflets suborbicular or broadly oval, mostly rounded at the apex; hypanthium in fruit obovoid or broadly ellipsoid, abruptly contracted at the apex; sepals tardily deciduous or persistent.	3. *R. rubiginosa.*
Leaflets ovate or oval, acute or short-acuminate; hypanthium in fruit narrowly ellipsoid, tapering at both ends; sepals early deciduous; styles glabrous or nearly so.	4. *R. micrantha.*

* Bull. Torrey Club 47: 47. 1920.

3. ROSA RUBIGINOSA L.

The European sweet brier, often cultivated, has established itself at several places in Oregon and Washington. It is very variable and the naturalized specimens show also much variation. One of these many forms, which is rather more glandular than usual, was mistaken for a native species and published by Dr. E. L. Greene as new, under the name *R. Walpoleana*. The author placed it in the GYMNOCARPAE, a group to which it has no relation.

4. ROSA MICRANTHA Borrer

See Bull. Torrey Club **47**: 49. 1920. This species also is naturalized in Oregon and Washington.

III. CINNAMOMIAE

Infra-stipular prickles not present; branches unarmed or bristly, not prickly.
- Stem densely bristly even in age; flowers solitary.
  - Hypanthium decidedly pear-shaped or ellipsoid, acute at the base, with a distinct neck at the top.
    - Sepals rarely more than 1 cm. long; bark yellowish green. — 5. *R. collaris.*
    - Sepals 2–3 cm. long; bark brown.
      - Leaflets obovate, sparingly hairy beneath. — 6. *R. Bulleri.*
      - Leaflets elliptic, densely pubescent beneath. — 7. *R. acicularis.*
  - Hypanthium subglobose, almost without a neck. — 8. *R. Bourgeauiana.*
- Stem unarmed or when young covered with more or less deciduous bristles; flowers corymbose.
  - Fruit ellipsoid; leaflets serrate. — 32. *R. Pringlei.*
  - Fruit subglobose; leaflets crenate. — 9. *R. anacantha.*

Infra-stipular prickles present.
- Flowers mostly solitary; petals usually 2.5 cm. long or more (except in No. 11); hypanthium in fruit 12–20 mm. thick.
  - Prickles straight or nearly so.
    - Hypanthium densely prickly. — 10. *R. MacDougalii.*
    - Hypanthium not prickly or rarely slightly so.
      - Leaflets more or less double-toothed, more or less glandular-granuliferous beneath; stipules and rachis glandular.
        - Pedicels and calyx densely bristly but hypanthium glabrous; leaflets oval, rarely 2 cm. long; prickles weak; petals 15 mm. long. — 11. *R. yainacensis.*
        - Pedicels and calyx not bristly, sometimes slightly glandular-hispid.

Leaves very thin, pale and slightly glandular-puberulent, but not muriculate beneath. 12. *R. Nutkana.*

Leaves thicker, dark green on both sides, conspicuously glandular-muricate beneath. 13. *R. muriculata.*

Leaflets simple-toothed, puberulent beneath, but not glandular-granuliferous or -muricate; rachis rarely glandular. 14. *R. Spaldingii.*

Prickles more or less curved.

Prickles very large, flat, pubescent; twigs densely glandular and pubescent. 15. *R. Durandii.*

Prickles slender, glabrous, not conspicuously flattened; twigs not conspicuously glandular, mostly glabrous.

Sepals not glandular-hispid; leaflets 2–4 cm. long, not conspicuously glandular double-toothed. 16. *R. columbiana.*

Sepals conspicuously glandular-hispid; leaflets 1–2 cm. long, conspicuously glandular double-toothed. 17. *R. myriadenia.*

Flowers mostly corymbose, if solitary the petals 2 cm. long or less; fruit rarely more than 1 cm. in diameter.

Prickles more or less curved.

Leaflets softly villous beneath; prickles stout, flattened; hypanthium with a neck. 18. *R. californica.*

Leaflets very finely puberulent and somewhat glandular-pruinose beneath; prickles not flattened; hypanthium without a distinct neck.

Leaflets with simple teeth, not copiously glandular-pruinose beneath. 19. *R. puberulenta.*

Leaflets with double gland-tipped teeth, conspicuously glandular-puberulent beneath. 20. *R. delitescens.*

Prickles straight or nearly so.

Hypanthium normally neither prickly or bristly.

Hypanthium globose; neck usually obsolete.

Sepals lanceolate, with long, caudate-attenuate or sometimes foliaceous tips, more than 1 cm. long.

Stipules, petiole, and rachis copiously glandular; leaflets double-toothed, with gland-tipped teeth, densely glandular-pruinose or muriculate beneath.

Leaflets orbicular or rounded oval. 13. *R. muriculata.*

Leaflets oblong to oval. 22. *R. Fendleri.*

Stipules, petiole, and rachis not glandular or the stipules slightly glandular-dentate.

Leaflets glabrous or nearly so.
Leaflets broadly oval, 3–5 cm. long. 21. *R. rivalis.*
Leaflets obovate or elliptic, rarely 3 cm. long. 23. *R. Woodsii.*
Leaflets more or less pubescent beneath.
Leaflets villous or pilose beneath, rounded or broadly oval. 25. *R. myriantha.*
Leaflets finely puberulent beneath.
Leaves obovate, more or less pale or glaucous beneath; prickles comparatively long, spreading. 24. *R. Macounii.*
Leaflets elliptic or oval, equally green on both sides; plant with few short ascending prickles.
Sepals decidedly glandular; leaflets thin and soft. 26. *R. pisocarpa.*
Sepals not glandular, or slightly so on the margins; leaflets rather thick. 27. *R. ultramontana.*
Sepals ovate, less than 1 cm. long, not conspicuously caudate; leaflets simple-toothed; puberulent beneath. 28. *R. Covillei.*
Hypanthium elongate with a distinct neck; leaves finely puberulent beneath.
Leaflets light green, coarsely toothed; hypanthium in fruit pyriform. 31. *R. pyrifera.*
Leaflets dark green above, finely toothed; hypanthium in fruit ellipsoid.
Plant unarmed or nearly so; fruit 1 mm. broad. 32. *R. Pringlei.*
Plant with slender prickles; fruit 6–8 mm. broad. 33. *R. Eastwoodiae.*
Hypanthium densely bristly or prickly; leaflets orbicular in outline.
Leaflets subsessile. 29. *R. spilhamea.*
Leaflets with petiolules, 1–4 mm. long. 30. *R. adenocarpa.*

5. ROSA COLLARIS Rydberg

The following specimens are doubtfully referred to this species: WASHINGTON: Fort Colville, 1880, *S. Watson 123*.

6. ROSA BUTLERI Rydberg

This species belongs to the Rocky Mountain region and was originally described from northwestern Montana. The following specimens from British Columbia are referred here:

BRITISH COLUMBIA: Camloops, May 24, 1912, *A. Thorpe.*

7. ROSA ACICULARIS Lindl.

See Bull. Torrey Club. **47**: 56. 1920. This is a common species throughout the northern Rockies and the Cascade Mountains.

8. ROSA BOURGEAUIANA Crépin

See notes in Bull. Torrey Club **47**: 57. 1920. In the Columbia region, this species has been found only north of the Canadian boundary.

BRITISH COLUMBIA: Okanogan Landing, Golden, *Pense;* Skeena River, *J. K. Henry.*

9. ROSA ANACANTHA Greene

This species is related to the eastern *R. blanda*, but differs in the crenate instead of serrate leaflets and the smaller fruit. It is known only from the type locality, in salt marshes near Tacoma, Washington.

10. ROSA MACDOUGALII Holz.

This is regarded by many as a form of *R. Nutkana.* It differs not only in the hispid fruit but also in the fact that the teeth of the leaflets are seldom double as they are in *R. Nutkana* and the leaflets are rarely glandular-granuliferous. Neither could it be referred as a form of *R. Spaldingii*, for in the latter the leaflets are pubescent beneath. The following specimens belong here:

IDAHO: Landing-Cuprum road 1901, *Cusick 2533, 2352;* Farmington Landing, 1892, *Sandberg, MacDougal & Heller 572, Heller 3256.*

OREGON: Rye River Valley, *Leiberg 4410.*

WASHINGTON: Pullman, 1896, *Elmer 72, 74.*

11. ROSA YAINACENSIS Greene

Until lately this species was known only from the type locality. The habit, long prickles, and large fruit suggest *R. Nutkana*, but

it is unique in the group on account of its densely glandular-bristly pedicels. It evidently is a good species unless of hybrid origin. It might have been produced by *R. Nutkana* and *R. gymnocarpa*.

OREGON: Yainax Indian Reservation, *Mrs. Austin*.

CALIFORNIA: Crescent City, Del Norte County, 1912, *Eastwood 2270*.

12. ROSA NUTKANA Presl

Although an easily distinguished species (except from the two next following species), it has been mistaken for *R. fraxinifolia* (i.e. *R. blanda*) and *R. Woodsii*. It has also been named *R. caryocarpa* Dougl. and *R. Lyalliana* Crépin; but these names have not been published, except in synonymy.

13. ROSA MURICULATA Greene

This is closely related to *R. Nutkana* and is perhaps not distinct. It differs in the thicker and smaller leaves, densely glandular-muricate beneath, and in the often corymbose inflorescence. As it is more common on the Vancouver Island than the preceding species, there may be a possibility that it is the original *R. Nutkana* Presl. In such a case the plant known as that species would be without a published name.

14. ROSA SPALDINGII Crépin

This has been confused with *R. Nutkana* but differs in the simple-toothed leaflets, which are decidedly pubescent but scarcely at all glandular-granuliferous beneath. Dr. Watson merged it in *R. Nutkana*, and this fact probably influenced Crépin to withdraw his species. The plant had been recognized before: Borrer in Hooker's Flora included it in *R. cinnamomea*, which it approaches more than any other American species does, differing principally in the longer and straight prickles; Nuttall recognized it as a species, *R. megacarpa*, but this name was published only as a synonym in Torrey & Gray's Flora; in the meantime Rafinesque had published it as *R. macrocarpa* Nutt. It is common through the northern Rockies as well as the Cascades.

15. ROSA DURANDII Crépin

This was based on *E. Hall 146*, which was referred to *Rosa kamtschatica* by Dr. Gray. Dr. Watson in his monograph reduced it to a synonym of *R. Nutkana*. Crépin, probably influenced by Watson's treatment, later retracted his species. In my opinion *R. Durandii* is perfectly distinct from *R. Nutkana*. The leaves are thicker, more hairy than in that species, and rarely double-toothed; the prickles are not like those of *R. Nutkana*, but curved, short, strongly flattened and pubescent. As long as only Hall's specimens were known, the specimens might have been regarded as freaks, but specimens almost exactly like these have since been collected.

OREGON: *E. Hall 146;* Brownville, 1895, *Canby;* near Springfield, *Coville & Applegate 1076*.

BRITISH COLUMBIA. Queen Charlotte's Island, *Dawson 8144* (?).

IDAHO: Lower Priest River, *Leiberg 2883*. This specimen is very peculiar, nearly unarmed, but with the pubescence of the leaves and twigs of *R. Durandii*.

16. ROSA COLUMBIANA Rydberg

This also is related to *R. Nutkana* but differs in the strongly curved prickles. It is a rather local plant, the following specimens belonging here:

IDAHO: Little Potlatch River, 1892, *Sandberg, MacDougal & Heller 381;* Kooteney County, *Sandberg*.

OREGON: Forest Grove, 1893 and 1894, *Lloyd*.

17. ROSA MYRIADENIA Greene

This species has the habit, toothing, and glandular pubescence of *R. muriculata*, but the leaflets are smaller and the prickles are decidedly curved; these characters would place it in the key next to *R. columbiana*. From this it differs in the smaller and more pubescent leaves. It is known only from the type locality, Huckleberry Mountains, Jackson County, Oregon.

18. ROSA CALIFORNICA Cham. & Schlecht.

This Californian species has been collected in the extreme southern part of Oregon.

19. ROSA PUBERULENTA Rydberg

This species belongs to the Great Basin and is related to *R. arizonica* and *R. neomexicana*. The following specimens are referred here, though somewhat doubtfully:

WASHINGTON: Wilson Creek, *Sandberg & Leiberg;* Rattlesnake Mountains, *Cotton 469*.

OREGON: Antelope Creek, *Applegate 2399;* Cold Spring, *Coville & Applegate 1122;* Wallowa, *Samson & Pearson 78*.

20. ROSA DELITESCENS Greene

This is related to *R. californica* but characterized by the double-serrate leaflets, glandular-pruinose beneath and with gland-tipped teeth, and by the subglobose fruit. It is known only from the type locality in the Siskiyou Mountains, Oregon.

21. ROSA RIVALIS Eastwood

This species belongs to the Californian flora (see notes, Bull. Torrey Club 44: 74. 1917) but the following specimen has been collected in Oregon:

OREGON: Cold Spring, Crook County, 1898, *Coville & Applegate 131*.

22. ROSA FENDLERI Crépin

23. ROSA WOODSII Lindl.

24. ROSA MACOUNII Greene

These three species belong to the Rocky Mountain region but extend west into the Cascade Mountains. They will be treated in a subsequent paper.

25. ROSA MYRIANTHA Carr.

This is primarily a Californian rose (see notes, Bull. Torrey Club 44: 75, 76. 1917), but the following specimens belong here:

OREGON: Barlow Gate, *Lloyd;* lower Albina, Portland, *Sheldon 10659;* Wimmer, *Hammond 119*, in part.

26. ROSA PISOCARPA A. Gray

27. ROSA ULTRAMONTANA (S. Wats.) Heller

These two species have been treated previously, under the Roses of California and Nevada (see Bull. Torrey Club 44: 77, 78. 1917). Though the former has its best development in the

Columbia region, especially west of the Cascades and the latter in the northern part of the Great Basin, which includes eastern Oregon, both extend north into British Columbia.

28. ROSA COVILLEI Greene

This species and *R. Bolanderi* are characterized among the cinnamon roses by the short ovate, short-acuminate sepals. *R. Covillei* is known only from the type locality, near Naylor, Klamath County, Oregon.

29. ROSA SPITHAMAEA S. Wats.

This species of northern California has been collected at one locality in the Columbia region:—

OREGON: Wimmer, *Hammond 120.*

30. ROSA ADENOCARPA Greene

Notwithstanding Dr. Greene's remark, "despite all its peculiar characteristics, a genuine member of this gymnocarpa group," I am compelled to exclude it. The upper part of the hypanthium and calyx show no sign of being deciduous, the sepals are not those short ones of the *R. gymnocarpa* allies, and the hypanthium is bristly. These characters and the dwarf herbaceous stems indicate that the plant is related to *R. spithamaea*, where I have placed it. It is known only from the type locality, Mt. Grayback, southwestern Oregon.

31. ROSA PYRIFERA Rydberg

This species is related on one hand to *R. Macounii* and on the other to *R. ultramontana* and *R. pisicarpa*, but differs from them all in the pear-shaped hypanthium, which has a more distinct neck. It is common in the northern Rockies, but the following specimens are from the Columbia region:—

WASHINGTON: Clarks Spring, *Kraeger 47.*

OREGON: Powder River Mountains, 1896, *Piper;* Horse Creek Canyon, *Sheldon 8138;* Thompson Creek, *Brown 86;* Ashland, *Walpole 375;* Tygh Valley, *Walpole 336;* Cow Creek, *Coville 1162;* Blue Mountains, *Cusick 1697.*

32. ROSA PRINGLEI Rydberg

See notes, Bull. Torrey Club 44: 79. 1917. The following specimens are from the region:

OREGON: Wallowa River, 1897, *Sheldon 8687* (?).

WASHINGTON: Klickitat County, 1885, *Suksdorf.*

BRITISH COLUMBIA: Armstrong Pass, 1912, *E. Wilson;* Elgin, *Miss Edstrom.*

33. ROSA EASTWOODIAE Rydberg

This is related to *R. Pringlei* but the plant has smaller leaves, smaller flowers and fruit, and is usually prickly. The fruit is only 6–8 mm. in diameter. To this belong:—

CALIFORNIA: Sisson, Siskiyou County, 1912, *Eastwood 2100,* mainly.

OREGON: Waldo, Josephine County, 1912, *Eastwood 2168.*

IV. GYMNOCARPAE

Leaves glabrous beneath.

Flowers mostly 2–4 together, leafy-bracted; upper stipules broadly dilated; leaflets with broadly ovate teeth, indistinctly reticulate beneath; fruit 6–8 mm. broad. — 37. *R. dasypoda.*

Flowers usually solitary, not leafy-bracted; stipules narrow; leaflets with lanceolate or ovate lanceolate teeth; fruit 6 mm. in diameter or less.

Leaves not very thin, pale and indistinctly reticulate beneath; sepals 1–1.5 cm. long. — 35. *R. leucopsis.*

Leaves very thin, scarcely paler on the lower surface, which is distinctly reticulate with semi-pellucid veinlets; sepals less than 1 cm. long.

Leaflets 5–7, usually more than 1.5 cm. long; teeth ovate-lanceolate in outline; terminal leaflet usually rounded at the base. — 34. *R. gymnocarpa.*

Leaflets 7–9, usually less than 1.5 cm. long, the terminal one usually acute or cuneate at base; teeth lanceolate in outline. — 36. *R. prionota.*

Leaves pubescent beneath. — 38. *R. Bridgesii.*

34. ROSA GYMNOCAPRA Nutt.

This species is one of the most common roses in the Columbia region (see my notes, Bull. Torrey Club 44: 82. 1917). As stated there Dr. Greene described twelve species belonging to the group and some of these will be discussed here.

Rosa glaucodermis Greene. Dr. Greene pays especial attention

to the ashy gray bark and the petioluled leaflets, characters which I think are not distinctive. In the typical *R. gymnocarpa* the bark is often light in color on old stems, and many specimens from the range of the typical *R. gymnocarpa* have more or less petioluled leaflets, such as *Jones 1088* and *R. S. Williams 876* from Montana, *Sheldon 8521* from Oregon, and *Allen 72* from Washington. I therefore regard this as a synonym of *R. gymnocarpa*.

Rosa abietorum Greene, I take as an unusually bristly *R. gymnocarpa*. I have been unable to find any constant character.

Rosa amplifolia Greene. I have not been able to distinguish this from *R. gymnocarpa*. Dr. Greene's remarks, "the leaves are so very large and have so much the color, texture and pattern of *R. acicularis*, that but for the small solitary flowers this would have passed readily with many for that species," are at least confusing. *R. acicularis* has rather thick, elliptic leaflets, decidedly pubescent beneath. Dr. Greene must have had an erroneous idea of *R. acicularis*.

35. ROSA LEUCOPSIS Greene

This is so close to *R. gymnocarpa* that I hesitated to admit it as a species. In *R. gymnocarpa* and *R. prionota* the leaflets are very thin and reticulate with semi-pellucid veins. In *R. leucopsis* the leaves are not so thin and the veins are faint and not at all pellucid. Otherwise the three plants are very similar. The species was described from fruiting material; the plant becomes paler in age.

Rosa Helleri Greene is evidently the same plant in flowers and shows only slight variation from the type of *R. leucopsis*. The Idaho specimens are mostly like those of the type of *R. Helleri*, but two numbers of Sandberg, MacDougal & Heller are almost identical with the type of *R. leucopsis*.

36. ROSA PRIONOTA Greene

This has been discussed before (see Bull. Torrey Club 44: 32. 1917).

Rosa piscatoria Greene I regard as an unusually strong and bristly plant of *R. prionota*.

Rosa apiculata Greene was so named on account of the form

of the fruit, "which is elongated, fully twice as long as broad, ending in a narrow necklike apiculation." The type sheet bears eight fruits. Of these only four are twice as long as broad, three are ellipsoid, but not as long, and one is nearly globose, slightly pear-shaped; four of them (three of the longer and one of the short-ellipsoid ones) have a conspicuous neck; one of the short-ellipsoid ones has no neck and the other three a short one. Miss Cooley's specimens from Vancouver Island, which from the locality should belong to this species and which agree with it in all respects except the fruit, has three fruits. One of these is elongated-ellipsoid, one somewhat pear-shaped and one subglobose; all with obsolete neck. They cannot be distinguished from *R. prionota*.

To *R. prionota* belongs the following specimens from the Columbia region:

WASHINGTON: Whiddley Island, *Saunders* (type of *R. apiculata*).

BRITISH COLUMBIA: Nanaino, *Miss Cooley*.

36. ROSA DASYPODA Greene

See notes, Bull. Torrey Club **44**: 83. 1918. To this species belong the following specimens:

OREGON: Wallowa County, *Sheldon 8815* and several other numbers; Siskiyou Mountains, *Applegate 2251;* without locality, *E. Hall 143;* Toledo Canyon, *Rusby;* Wimmer, *Hammond 117*.

WASHINGTON: Chehalis County, *Heller 3897*.

BRITISH COLUMBIA: Chilliwack Valley, *Macoun 79841, 24748;* between Kettle and Columbia River, *Macoun 64008, 64007;* Esquimalt, *Macoun 79840*.

37. ROSA BRIDGESII Crépin

See Bull. Torrey Club **44**: 83. 1917. To this species belong the following:—

OREGON: between Union Creek and Whiskey Creek, *Applegate 2622;* Huckleberry Mountains, *Coville 1434*.

HYBRIDS

The following hybrids have been recorded from this region:—

ROSA ACICULARIS × FENDLERI

BRITISH COLUMBIA: Golden, *J. K. Henry*.

ROSA ACICULARIS × MURICULATA

BRITISH COLUMBIA: Narramantha, Lake Okanogan, *J. K. Henry.*

ROSA BOURGEAUIANA × MURICATA

BRITISH COLUMBIA: Hazelton, Skeena River 1915, *J. K. Henry.*

ROSA GYMNOCARPA × NUTKANA

BRITISH COLUMBIA: Crescent 1915, *J. K. Henry.*

ROSA NUTKANA × PISOCARPA

BRITISH COLUMBIA: Savannas, 1892, *F. E. Lloyd.*

ROSA PISOCARPA × SPALDINGII

EASTERN OREGON: 1900, *Cusick 2418.*

ROSA GYMNOCARPA × PISOCARPA

OREGON: Siskiyou Mountains, 1904, *Render.*

ROSA GYMNOCARPA × MURICULATA

BRITISH COLUMBIA: Cameron Lake, Vancouver Island, 1912, *J. K. Henry.*

ROSA GYMNOCARPA × WOODSII

BRITISH COLUMBIA: Skeena River 1915, *J. K. Henry.*

NEW YORK BOTANICAL GARDEN

On the gross structure of an agar gel

CORNELIA LEE CAREY

(WITH FOUR TEXT FIGURES)

In connection with some other work on the behavior of agar gels a peculiar appearance was noticed in certain dried strips of agar which had been swollen in water. In these cases the swollen gels, when removed from the water, would exude a considerable amount of the adsorbed liquid under slight pressure. This led to an examination under the microscope, where it was found that the gel had a decided lamellated structure. Later it was noticed that these lamellations were visible to the naked eye and could be seen when light was reflected upon the cut surface. It seemed of interest to investigate some of the causes influencing the formation of this structure, and the relation its appearance might bear to the concentration of the gel.

A brief notice of this phenomenon has already been published in D. T. MacDougal's recent contribution on hydration and growth* from data supplied by the writer.

The method of preparing the agar was that used by MacDougal and described by him in this paper, except that silk was used to cast the agar upon instead of filter paper, as the former could be more easily removed from the agar than the latter. Prepared in this way, the gels were at first allowed to stand over night in the room, and then dried at a temperature of about 70° C. It was found, however, that this first slower drying in the room had no effect on the structure, as gels put immediately into the dryer as soon as set had the same appearance. It is, of course, to be understood that the lamellations did not appear until the dried gel had been again swollen in water.

In order to ascertain whether the tension due to the drying on the silk had anything to do with the structure of the gel, a 2.5 per cent gel was cast as usual, but instead of being stretched on a frame it was cut into strips as soon as set. Some of these were

* Hydration and growth. Carnegie Inst. Washington Pub. No. 297, 1920.

hung up in the drier; others laid horizontally on the trays in the same at temperatures of about 43° C. and 70° C. Both of these showed the characteristic structure on swelling. Similar gels were dried at room temperature, 21–25° C., both stretched on frames and cut into strips. Some of the latter were either suspended or laid horizontally across supports. None of these showed any structure at all when soaked in water and sectioned, but were homogeneous throughout. A few of the gels dried at room temperature showed slight lamellations in places on the under side of the gel near the silk, but this was not so in all cases. It is apparent from the above, that the temperature and therefore perhaps the speed of drying may be an important factor in producing this lamellated structure.

Gels of varying per cents of agar content were employed for this work, from 0.5–10 per cent. They all showed structure when dried at 70° C. A 0.25 per cent gel was tried but was too weak to set at room temperature. The following concentrations of gels, expressed in per cent content of dry powdered agar, were used: 0.5, 0.75, 1, 1.5, 2.5, 3, 4, 5, 7.5, 8, and 10 per cent. The 4 per cent gel was used to determine the point at which structure appeared as loss of water proceeded.

It seems probable that this structure must form when a certain water concentration is reached in the drying of the gel. In order to ascertain at about what concentration the formation of structure began and was complete, a 4 per cent agar gel was made and, when set, cut into pieces four by two and a half inches. Each piece was placed between a pair of tin frames which were held together by two elastic bands. Each frame had two holes in it one by one and a half inches. The whole apparatus with the agar was then put in the drier, for varying lengths of time, at a temperature of about 90° C. It was turned over at short intervals so that loss of water would be equalized on the two sides. The slices did not split during the process and were removed very easily from the frames. A portion of the pieces was cut off and put into distilled water; the other part weighed, put back into the drier and finally dried to constant weight in a calcium chloride desiccator. The part put into the water was sectioned after about twenty-four hours to see if there was any structure present.

TABLE I

PER CENT BY WEIGHT OF WATER AND AGAR IN A 4 PER CENT AGAR GEL WHEN NO STRUCTURE PRESENT

Weight of gel when removed from drier in grams	Final weight of gel in grams	Weight of water in piece when removed from drier	Per cent of water to total weight	Per cent of agar to total weight
2.254	.177	2.077	92.15	7.85
3.092	.221	2.871	92.88	7.12
2.692	.194	2.498	92.79	7.21
			92.61	7.39

TABLE II

PER CENT BY WEIGHT OF WATER AND AGAR IN A 4 PER CENT AGAR GEL WHEN STRUCTURE BEGINS

Weight of gel when removed from drier in grams	Final weight of gel in grams	Weight of water in gel when removed from drier	Per cent of water to total weight	Per cent of agar to total weight
2.331	0.181	2.150	92.24	7.76
2.351	.170	2.181	92.77	7.23
3.252	.208	3.044	93.60	6.40
1.512	.157	1.355	89.62	10.38
2.172	.172	2.000	92.08	7.92
1.959	.172	1.787	91.22	8.78
2.174	.186	1.988	91.44	8.56
			91.85	8.15

TABLE III

PER CENT BY WEIGHT OF WATER AND AGAR IN A 4 PER CENT AGAR GEL WHEN STRUCTURE IS COMPLETE

Weight of gel when removed from drier in grams	Final weight of gel in grams	Weight of water in gel when removed from drier	Per cent of water to total weight	Per cent of agar to total weight
0.306	0.235	.071	23.20	76.80
.245	.165	.080	32.65	67.35
.322	.223	.099	30.74	69.26
.289	.203	.086	29.75	70.25
.292	.225	.067	22.95	77.05
.268	.225	.043	16.04	83.96
.234	.209	.025	16.83	83.17
.215	.175	.040	18.60	81.40
.209	.196	.013	6.22	93.78
.264	.195	.069	26.14	73.86
.210	.206	.004	1.91	98.09
.279	.199	.080	28.67	71.33
.241	.219	.022	9.13	90.87
.321	.201	.120	37.38	62.62
.327	.211	.116	35.47	64.53
.306	.212	.094	30.72	69.28
.257	.177	.080	31.13	68.87
.357	.219	.038	10.64	89.36
.210	.206	.004	1.90	98.10
.235	.178	.057	24.26	75.74
			21.72	78.28

From the larger piece, which was dried to constant weight, the per cent of water in the gel at the given time was obtained. This gave a fairly accurate estimate of the relation of water content to structure but cannot be regarded as strictly quantitative, as the electric heater did not give a wholly uniform temperature over all the drier so that when the time factor is constant a slight difference in the position of the strips when in the oven might vary the concentrations in them.

The tables on page 175 show the per cent by weight of water and agar in the gels: (*a*) when there was no structure present; (*b*) when it first began to appear; and (*c*) when the structure was complete. From comparison of TABLES I and II it will be seen that the critical point for structure formation lies between about 92 per cent and 92.5 per cent water content. This, however, is not the uniform concentration throughout the piece, since the surface would of course lose water first and the water content in the center of the gel would be higher than that on the edge, as it dries from the outside in and from the edge of the frame toward the center. The structure, as one would suppose, starts from the outside of the block and goes inward. This would necessarily be the way since the surface loses water first. The structure was complete, as shown in TABLE III, when the gel contained about 21.5 per cent by weight of water.

For the purposes of this paper the agar dried to constant weight in the desiccator was assumed to contain no water. The basis of the calculations was as follows: the per cent of water by weight to the total weight of substance was calculated by subtracting the final (constant) weight, obtained by drying the pieces of agar in a calcium chloride desiccator, from the first weight, after drying varying lengths of time in the oven. The loss of weight was therefore the per cent of water in the gel when structure became apparent. The pieces gained somewhat in weight while in the desiccator due to the vapor pressure of the calcium chloride. This was not taken into account as it is a constant error in all cases.

The structure varies in the different gels but is fundamentally the same. It appears as horizontal splitting in the gel, and when very pronounced as it was in most of them, particularly those

below 7.5 per cent, has somewhat the appearance of branching; the cavities being shaped in section like a biconvex lens. In the 10, 8, and 7.5 per cent gels there were fewer large cavities and more fine pores or slits (FIG. 4). In the weaker gels larger slits and fewer finer ones are seen (FIGS. 1–3).

The figures show a gradual change from the coarser to the finer structure as the per cent of agar in the gel increases. It seems as though this change probably commenced between the 5 and the 7.5 per cent gels though this has not been definitely determined. Narrower branching also appears if the gels are dried at high tempera: tures, i.e., more rapidly. Strips not dried on the frames showed structure, but curled somewhat in drying. The 2.5, 3 and 5 per cent gels after soaking in water could be peeled off in layers.

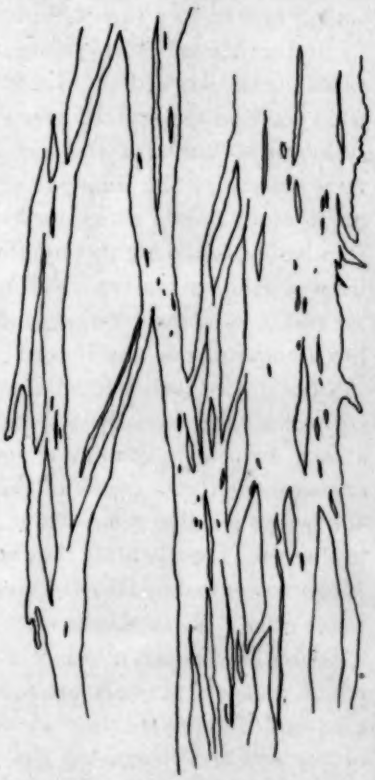

FIG. 1. A 0.5 per cent agar gel after being in water about one hour. × 57.

It seems possible that the structure of the gels, which when first set must be isotropic, becomes anisotropic on drying due to the strains set up within the mass. It would seem to the writer that the long axis of the particles, after drying, would be in the horizontal plane of the gel. This might cause splits in it in the horizontal and not in the vertical plane, as the water is withdrawn, as is the case here. This is, however, only a suggestion as the gels were not examined with a polariscope.

Ambronn* found that thin layers of agar and gelatine, when frozen and dried on glass plates, gave the appearance under the microscope of a fine network which, he says, looked almost like a

* Ber. Verhandl. Königl. Sachs. Ges. Wissens. Math. Phys. Kl. 1891: 28–31.

section of parenchymatic plant cells. He found the walls of the meshes were like those of normal cells, having a decided double refraction, and the smallest axis of the particles lying perpendicular to the surface of the partitions caused by freezing. He did not obtain this structure after freezing and drying either egg albumin or dextrin, as the glass became covered with a uniform coat of the substance. The agar and gelatine retained their structure unless heated to a high temperature.

Later Molisch,* in relation to his work on the freezing of plants, also worked on the freezing of gels. Among others he used gelatine and starch. He experimented with a 2 per cent gelatine which formed a stiff gel at room temperature. Under the microscope, at the moment of freezing, masses of ice appeared at different points which increased in size. When the ice formation had ended, a highly complicated network of gelatine remained between the ice masses. After thawing the network remained for several days as the gelatine could not adsorb the water at relatively low temperatures, and it could be fixed by treating with absolute alcohol. The starch acted in much the same manner. According to Molisch, on freezing a separation of the water and the colloid starts, in which numerous ice crystals are formed, which are enclosed by the network of the colloid. The ice is derived from the water of the gels. Such substances as white of egg, gum arabic, etc., shortly after thawing return to their original condition. Molisch compares this freezing to that of *Amoeba* and certain plant cells. He says cells may freeze like *Amoeba* and the stamen hairs of *Tradescantia*. Here the ice forms within the protoplast, which makes a network around it. Or they may freeze as *Spirogyra* and *Cladophora* do. In the latter case, the water comes out of the cell and freezes on the outside of the wall and there is a great shrinkage of the cell during the process. When cells freeze, as in the case of the colloidal gels, there is a strong dehydration since ice formation and shrinking of the protoplast go hand in hand. The spaces formed on thawing of the ice in Molisch's gelatine and starch were more spherical and less flattened than those obtained by the writer on desiccation of agar. This may be due to the shape of the ice crystals themselves, although it is

* Untersuchungen über das Erfrieren der Pflanzen. Jena. 1897.

perhaps unsafe to make a direct comparison, as Molisch did not work with agar.

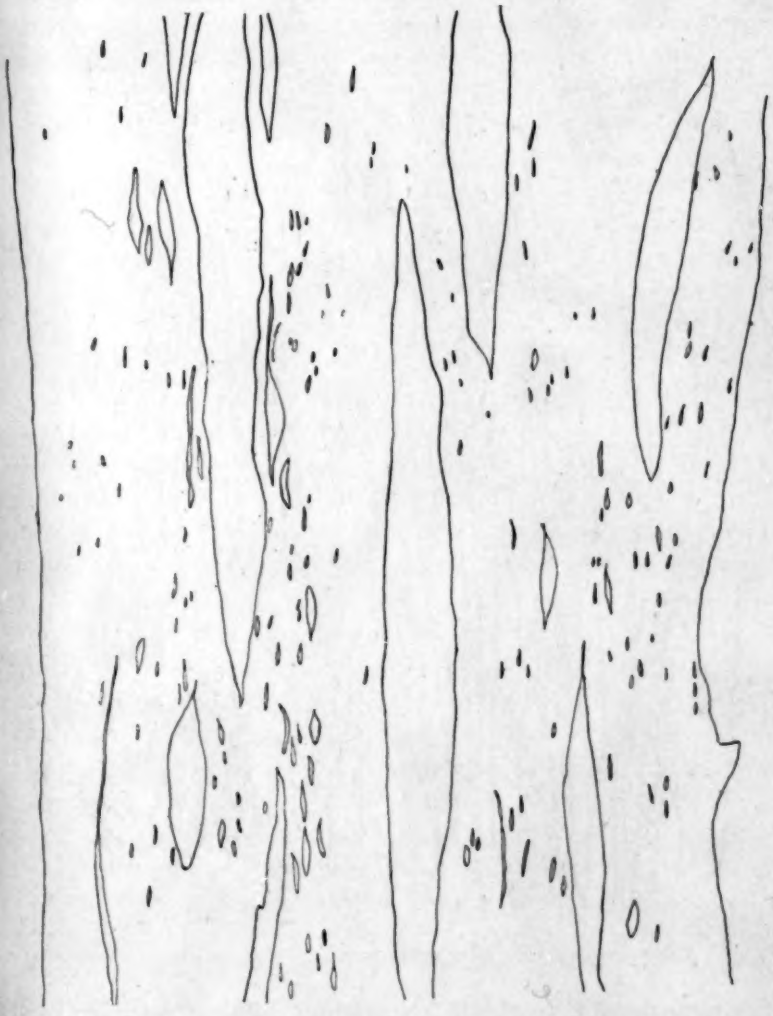

FIG. 2. A 2.5 per cent agar gel after drying at about 43° C. and soaking in water, × 57.

There seems to be a similarity between the effect of rapid dehydration due to freezing and rapid drying at higher temperatures and the structure of the gel. In both cases the water is

withdrawn, but in the case of the freezing it remains as ice or water surrounded by the gel; while in the other, it is immediately removed by the high temperature at which dehydration is carried on.

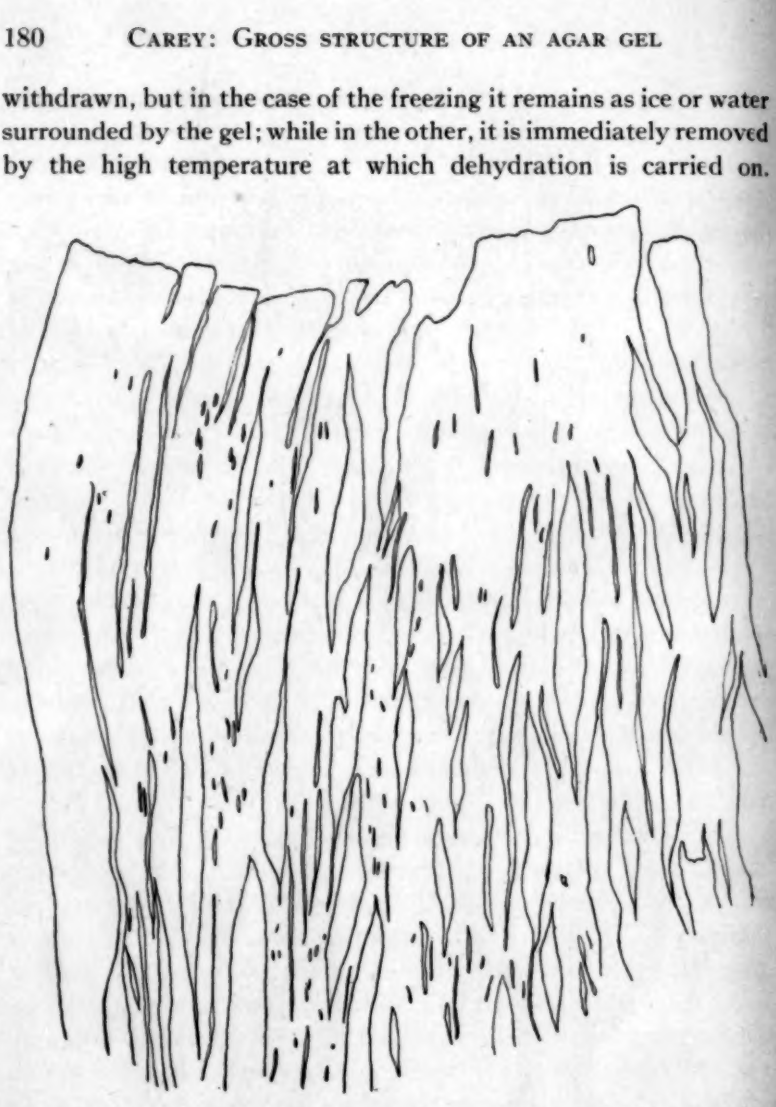

FIG. 3. A 5 per cent agar gel dried at about 70° C., after soaking in water. × 57.

If it were possible to obtain a structural colloidal gel made of a mixture of proteins and carbohydrates, one might be able to get similar results to those obtained in plant tissues, although it might be dangerous to carry this analogy too far.

The separation of colloidal fluid from gels on standing, known as syneresis, is a phenomenon which is more pronounced the

more hydrated the gel is. Fischer* accounts for the condition found in the tissues in oedema by means of syneresis, and MacDougal† considers syneresis as a means of vacuole formation after which osmotic pressure plays its part, the earlier stages being due to hydration.

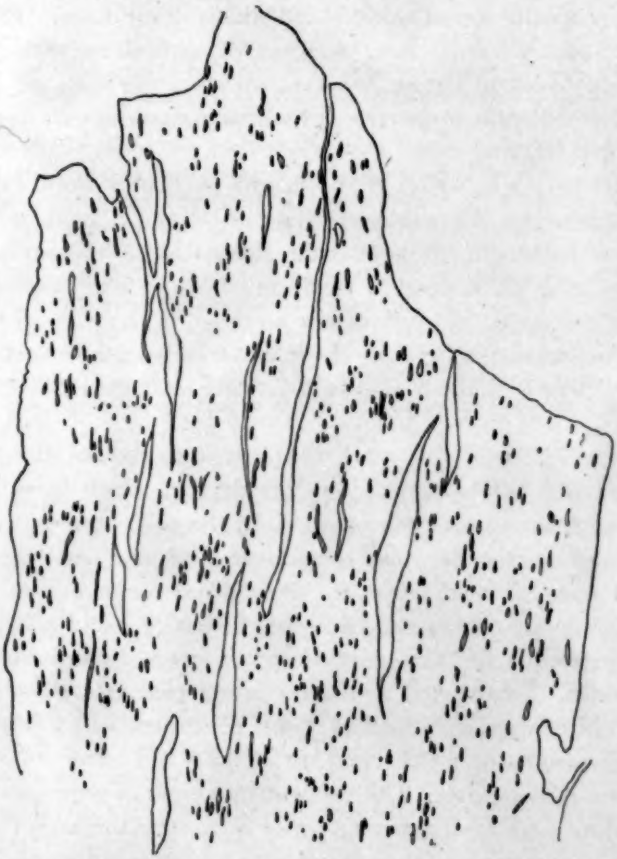

FIG. 4. A 7.5 per cent agar gel after drying at about 70° C. and soaking in water, × 57.

Zsigmondy‡ states that, if the reaction of dehydrated silicic acid gels toward hydrosols is observed under the microscope, the gel will be seen to break into small pieces. This, he says, is

* Oedema and nephritis. 1915.

† Growth in organisms. Science II. 49: 599–605. 1919.

‡ Chemistry of colloids. English edition. 1917.

due to the pressure on the air in the pores of the gel together with surface tension changes. The water enters the gel quickly at first. While this goes on explosions and splittings take place in the gel and air bubbles are formed at little cracks. As the bursting of the gel and the evolution of the air proceeds, the volume of the air spaces becomes smaller and finally disappears. He does not feel that there is any evidence of explosions with water. Zsigmondy was, of course, working with a non-elastic gel which has rather different properties of hydration and dehydration than elastic gels have.

Zsigmondy also writes that Bütschli and later work with the ultra-microscope have shown that with silicic acid gels the dehydration does not proceed from the outside of the gel inward, but that holes are formed in the interior of the gel. These holes contain no liquid. This does not seem to be the case with agar gels, when sections of the partly dehydrated gel are viewed under the microscope, as the first slits visible are near the surface of the gel.

It appears from this work that the structure of the gels is probably due to the rapidity of the drying, which in this case varied with the temperature used. All the gels showed structure except those dried at room temperature, the majority of which showed none; a few, however, showed one or two slits. The structure is not due to the strain of stretching on silk, as pieces dried suspended or laid on trays in the oven showed the same appearance. This varied somewhat in different gels, those above 5 per cent being finer. Gels of lower concentrations when dried at temperatures of 43° C. and 70° C. did not show any great difference in structure. The per cent by weight of water and agar just before and at the beginning of structure formation is not absolutely accurate, as the gel contains a higher water concentration inside than out, owing to the fact that the drying takes place from the outside inward.

I wish to express my appreciation and thanks to Dr. Herbert M. Richards for his most helpful advice and interest.

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INDEX TO AMERICAN BOTANICAL LITERATURE

1917–1921

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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